International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

TECHNOLOGICAL CAPABILITIES OF APPLICATION OF THERMOCYCLIC PROCESSING (TCP) TOOL STEEL

[1]Norkhudjayev F.R, [2]Mukhamedov A.A,[3] Ergashev D. M, [4] Hudayberdiyev O.R, [5]Djalolova S.T

ABSTRACT--*Thermocyclic processing (TCP) is based on the idea of repeated heating- cooling of steel without exposure at a continuous temperature of heating. At the same time, values of temperatures at the upper and lower levels and the speed of heating of cooling can be constants. The recurrence of thermal influences is caused by aspiration to accumulation in object of structural and phase changes. Unlike traditional heat treatment at TCP each subsequent thermocycle occurs on the basis of a new structural and phase status. It ultimately allows that after the last cycle of TCP or the completing heat treatment began to reach substantial increase of properties, which in combination of different characteristics in many cases is unattainable at traditional heat treatment. In this work the possibility of carrying out TCP not heat resistant tool steel using lubricoolant on the basis of water-soluble polymer of the medicine "Uniflock" is considered.*

Key word-- *thermocyclic processing, tempering, issue, water-soluble polymers, hardening liquid, cooling speed.*

I. INTRODUCTION

The scheme of thermocyclic processing (TCP) is based on repeated heating and cooling steel without exposure at a continuous temperature of heating [1]. The value of heating temperatures and cooling and speed of these processes are constant or change from a cycle to a cycle. Repeated impolyacrylamidet of heating and cooling, leads to accumulation of phase changes in structure of steel. In comparison with standard heat treatment at TCP it is possible to reach the increased properties of steel.

There is a large number of the TCP [2.3] on different modes. According to [3] all ways are divided into three views: low, average and high temperature ways. Low temperature way TCP is carried out at temperatures before $\alpha \rightarrow \gamma$ transformations. Medium temperature will convey in the range of temperatures between the points of A_c and A_{c3}.

High-temperature is conducted above a point of A_{c3} or A_{ct}. Perhaps, also carrying out the combined TCP modes with transition to different temperature areas. Medium and high-temperature TCP for tool steel is used

[1]*Doctor of Technical Sciences, Professor, Head of the Department "Materials Science" of the Faculty of Mechanics at Tashkent State Technical University, fayzulla.norxudjaev@tdtu.uz*

[2]*Associate professor, Doctor of Philosophy in Technical Sciences (PhD), "Materials Science" department at Tashkent State Technical University*

[3]*Senior teacher, Andijan machine building institute, Andijan, Uzbekistan, dilshodbek.ergashev@mail.ru*

[4]*Senior teacher, Andijan machine building institute, Andijan, Uzbekistan, E-mail: oribjonxudayberdiyev@gmail.com*

[5] *Senior teacher, "Materials Science" department at Tashkent State Technical University*

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

generally for implementation of process of annealing for the purpose of enlargement and spheroidization of carbides.

Low temperature TCP are conveyed rather seldom. Temperature intervals of conveying exclude phase transformations and generally convey to redistribution of defects of the crystal building. This type of processing by means of TCP is generally found in application for iron [4]. Dual hardening modes are also used, which are characterized as more effective than single [5]. The similar scheme includes the first tempering from the increased temperatures, the second subsequent tempering from standard temperature. At high temperature heating carbides, which then are selected at the second heating in the form of fine particles, are dissolved.

Most of the TCP optimum modes in terms of improvement of mechanical and technological properties are the modes of the combined TCP.

The combined TCP includes tempering from the increased or standard heating temperatures, intermediate issue and the subsequent standard heat treatment consisting of tempering from usually accepted temperatures and final issue.

In D.M. Berdiyev's work [6], it is shown that application of double tempering with intermediate issue of У8 steel is possible to increase wear properties level for stamps of cold deformation. It is possible to increase the high level of wear properties to be received for the account of crushing of grain and increase in density of dislocations. The first tempering spent from heating temperatures of 1100-1150 ℃ intermediate tempering 450 ℃. The second tempering from heating temperature 820 ℃ and final issue 180-200 ℃, on the hardness of HRC 60, the structure of steel after such heat treatment represents small needle martensite and residual austenite.

It should be noted that questions of application of TCP to tool steel are insufficiently studied. In particular application of medium temperature TCP for the spheroidizing annealing yielded positive results.

However influences of the annealing modes of TCP on the subsequent phase transformations at heat treatment were practically not studied. Instrumental steel work in the conditions of heavy loads for working edges of the tool, and application of the different modes of TCP is insufficiently approved because of difficulty of using high temperatures of heating under tempering which can lead to emergence of cracks in the course of tempering and also to the decarbonization phenomenon.

Therefore questions of a possibility of effective application of the TCP modes for carbonaceous and alloyed tool steel are relevant so far.

In most cases tool steel apply mineral oils to tempering as cooler. Well-known shortcomings have use of mineral oils: it is the high cost, high degree of inflammability, education when tempering oil mist.

In recent years works on research of substitutes of the oils used as hardening environments [7.8] were carried out. Many hardening environments – it’s solutions of different substances in water are most widely used water-soluble polymers. All hardening environments based on the water-soluble polymers produced in the CIS countries can be classified as follows.

On a basis:

- polyacrylamides (polyacrylamide and ЗСП-1);
- incomplete iron salt;
- polyacrylic acids (PC-2);
- solution water and alkaline methacrylic copolymers (УЗСП-1);

- sodium salt carboxyl methil cellulose (Na-КМЦ);
- copolymers of a chlorine with methyl methacrylate and methacrylic acid ("Nairit").

The majority of these environments received industrial application in particular PAA and (ЗСП-1) environment yields good results at premium tempering from induction heating.

Satisfactory results at volume tempering of thin-walled products are yielded by tempering in the environment based on Na-КМЦ [9].

Lack of water solution polyacrylamide(polyacrylamide) is the big instability of refrigerating capolyacrylamideity at temperature change. For the purpose of improvement of the cooling properties when tempering by immersion enter additives of mineral salts into polyacrylamide solutions: chloride sodium, soda, chloride ammonium. At the same time the maintenance of polyacrylamide is normal 0.2-0.5%.

Solutions on the basis of sodium-carboxymethyl cellulose (Na-КМЦ) are widely used at the Russian plants (NPO Atommash, the Rostselmash, etc.). Speed of cooling can be regulated concentration of Na-КМЦ polymer and mineral additives use 2% of Na-КМЦ from 2% drills. Cooling of large details in the environment of 1.5% of Na-КМЦ without adding of chloride sodium takes place more slowly, than in oil and solution has low firmness at operation. Because of that,15% of NaCl is added.

From all considered structures, solution based on copolymer of methacrylic acid with acrylonitrile in a ratio of mono measured links (90-10)-(50-50) on the weight and concentration of copolymer of 0.1-10.0% (УЗСП-1) is considered as universal. Extremely limited information is available about an opportunity to use as a component of the hardening environment, copolymer of acrylic acid and the acrylamide produced under the “Uniflock” trademark. At the same time need of development of the program of the standardized complex for certification of hardening environments substitutes of oil is emphasized.

II. METHODS

As objects of researches tool steels (У12, 9ХС) were selected.

Table 1: Chemical composition of investigated steels

Марка стали	C	Mn	Si	Cr	P	S
У12	1,2	0,4	0,25	-	0,03	0,025
9ХС	0,9	0,5	1,5	1,25	0,03	0,025

For a research of the modes of TCP thermocyclic processing used the heating modes, starting with usually accepted temperatures for these steel grades up to the temperatures of 1100-1150 °C. After that, samples of steel were thrown in the furnace with a temperature below A_{c1} on 20 °C, exposure at this temperature and having heated to the standard temperature of tempering with the subsequent cooling on air (fig. 1) again.

Final heat treatment for these steels consisted in conducted tempering from standard heating temperatures for every steel grades and cooling in waters to the polymeric environment of the medicine "Uniflock". Final tempering was spent cyclically in a pulsed mode when heating steel У12 to temperatures of 300-500 °C, steel 9ХС 450 °C, heating time at issue was selected proceeding from necessary time for warming up of the tool and made from 10 to 15 minutes. Subsequent cooling was conducted in waters to the polymeric environment on the basis of the medicine "Uniflock".

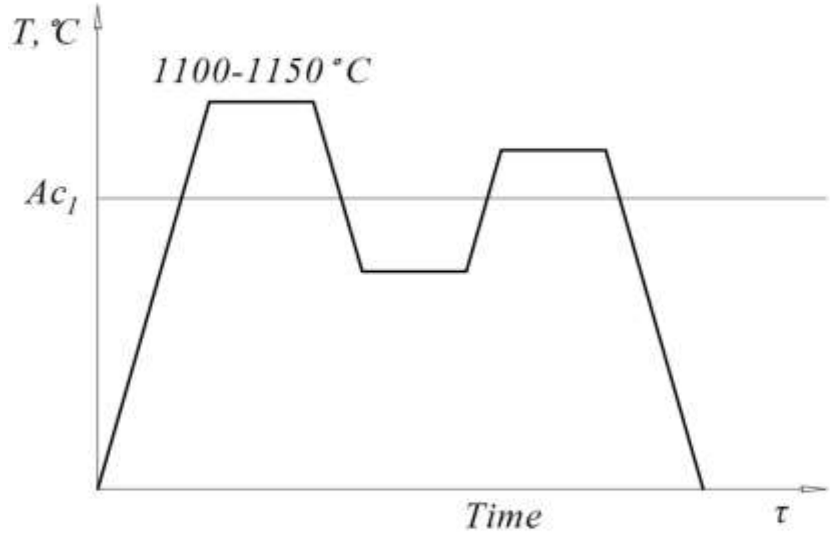

Figure 1: Scheme of preliminary TCP.

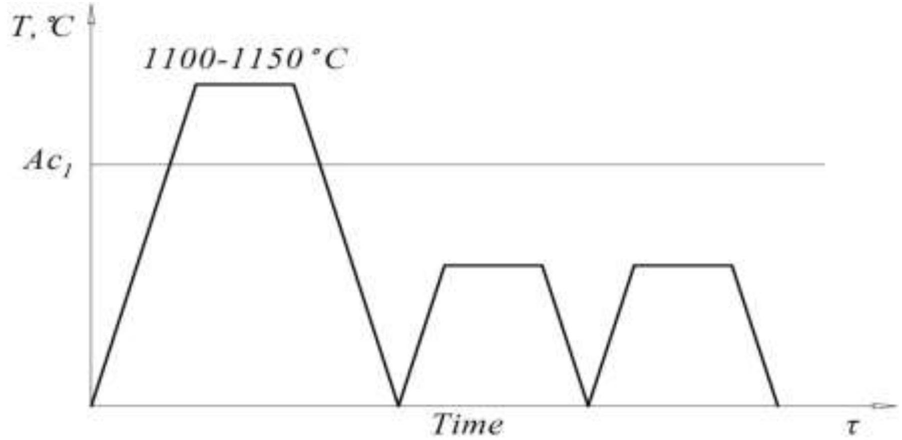

Figure 2: The scheme of final heat treatment of tempering from standard temperature of double discrete issue

Heating of steel was conducted in chemical bath of NaCl and $BaCl_2$. Steel samples tempered in water-soluble Na-КМЦ and "Uniflock" polymers at tempering. Refrigerating capolyacrylamideity of solutions of polymers was defined.

For definition of a status of a fine crystal structure of steel conducted the X-ray diffraction analysis. It is determined the physical width of x-ray lines of an interference α-phase. Shootings spent on DRON-2,0 installation in the radiation of the iron anode at a tension on a tube V=30-35 kV, a plate current J=9 MA.

III. RESULTS

Preliminary TCP was conducted according to the scheme on fig. 1 steel of the У12 and 9HS brands heated up to the extreme heating temperature of 1100-1150 ^{0}C. Existence of extreme temperatures of heating explain the fact that after cooling, it is formed the structure with a maximum deficiency of the crystal building which affects wear resistance of steel [6]. X-ray diffraction researches of preliminary TCP of steel У12 and 9HS showed that the maximum deficiency of the crystal building forms at these steels at application of the high-temperature modes of heating (fig. 3).

For the purpose of reduction of a fabrication cycle and reduction of hardening tension in steels, final heat treatment was conducted according to the scheme (fig. 2). Tempering was conducted from standard heating temperature of 820 ^{0}C for steel У12, 840 ^{0}C for steel 9XC, cooling in waters to the polymeric environment on the basis of the medicine "Uniflock". Tempering of steel was spent in a double discrete mode at different temperatures, with cooling in waters to the polymeric environment. X-ray diffraction researches showed that at application of preliminary TCP with high-temperature heating the structure with the high level of crystal deficiency in steel forms. At final heat treatment according to the scheme (fig. 2), there is an effect of inheritance of deficiency of the crystal structure at different temperatures of discrete issue. (fig. 4,5).

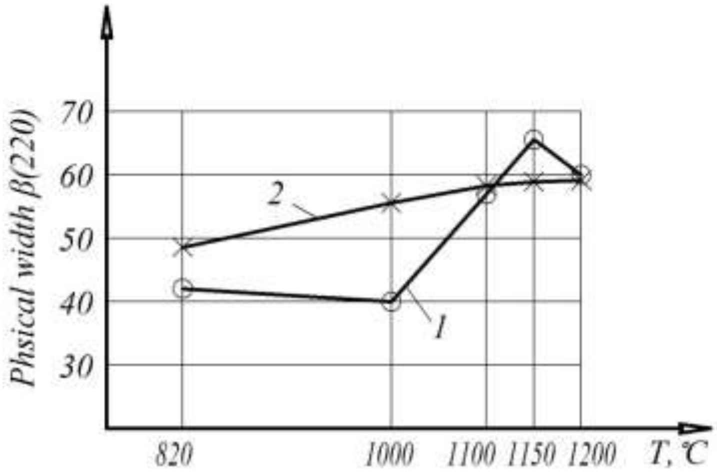

Figure 3: Dependence of Physical Width of the x-ray line (220) of steels У12 and 9XC depending on preheating temperature and temperature of final heating, cooling on air 1st steel У12, 2nd steel 9HS.

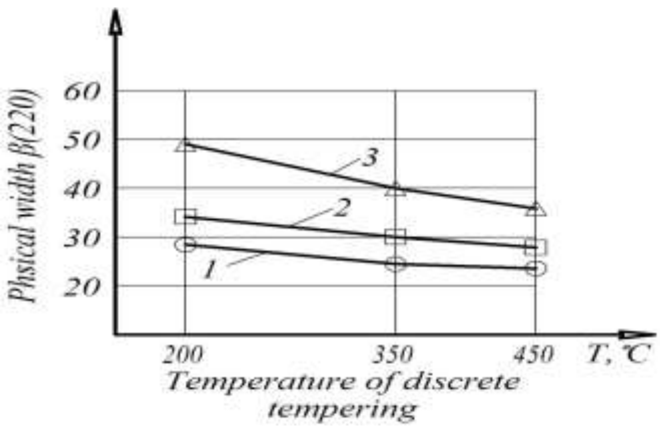

Figure 4: Dependence of physical width of the x-ray line (220) of steel У12 depending on temperature of final discrete issue.

Tempering of temperature at 820 ^{0}C.

1st Preliminary TCP from heating temperature at 820 ^{0}C.

2nd Preliminary TCP from heating temperature at 1000 ^{0}C.

3rd Preliminary TCP from heating temperature at 1150 ^{0}C.

For definition of optimum hardening lubricoolant based on water-soluble polymers were conducted by research of refrigerating capolyacrylamideity of these polymers in different concentration.

Preliminary experiments were made by removal of curves of cooling with the special thermometer made of steel 12X18H10T.

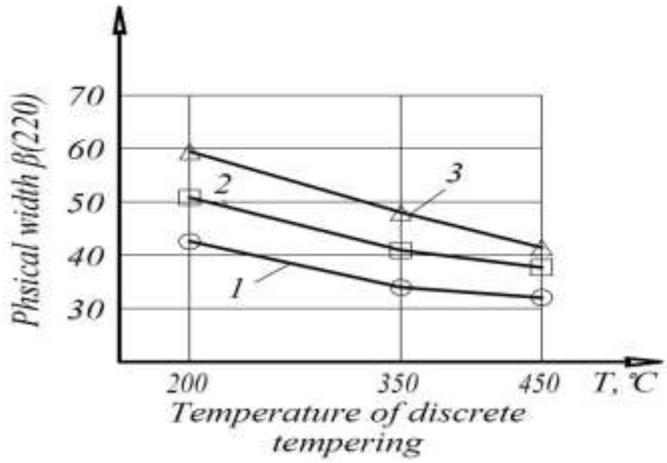

Figure 5: Dependence of physical width of the x-ray line (220) of steel 9XC depending on temperature of final pulse issue.

Tempering of temperature 840 ^{0}C.

1st Preliminary TCP from heating temperature 820 ^{0}C.

2nd Preliminary TCP from heating temperature 1000 ^{0}C.

3rd Preliminary TCP from heating temperature 1150 ^{0}C.

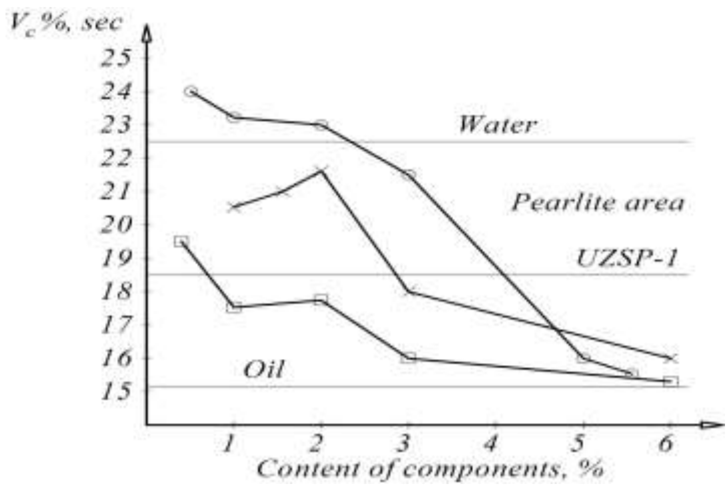

Figure 6: Influence of maintenance of polymeric components in hardening liquid on cooling speeds, an interval 870-275 ^{0}C. O- Na-КМЦ X-Uniflock, O- Na-КМЦ of 2% marked acrylate

The thermometer heated up in the furnace without the protective atmosphere to temperature of 870±5 ^{0}C and was maintained within 5 min. Then during less than 2 sec., moved in cooling medium. The volume of liquid was 2 l, and temperatures of liquid changed from 20 ^{0}C to 40 ^{0}C. Temperature changes in the course of cooling registered on a self-balancing potentiometer of КСП-4.

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

Cooling curves determined the average speed of cooling around perlite transformation, in the range of temperatures 870-275 ^{0}C, and in the range of temperatures of martensitic transformation for carbonaceous and low-alloy steels 275-55 ^{0}C (fig. 6.7).

Experiences showed that Na-КМЦ solutions are the least natural as cooling speed strongly depended on change of concentration of solution. Use of “Uniflock” solutions is in this respect more favorable. The required speeds of cooling corresponding of 0.7% to УЗСП-1 solution are reached at the maintenance of a component in solution about 3%.

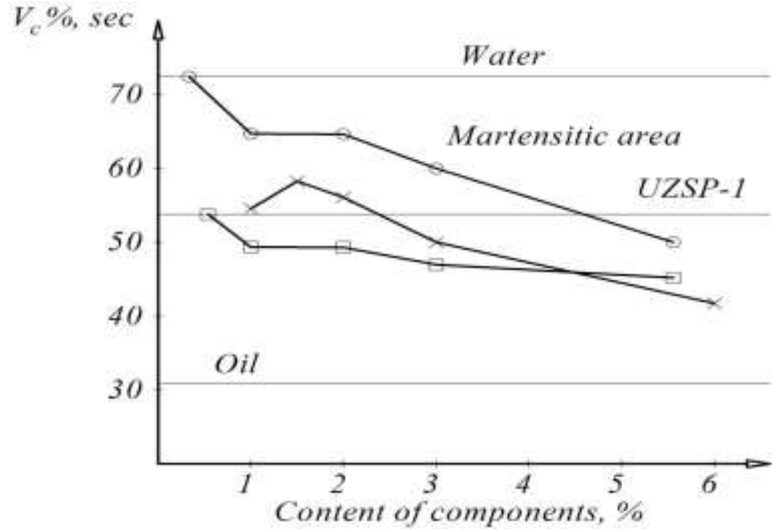

Figure 7: Influence of maintenance of polymeric components in hardening liquid on cooling speeds, an interval 275-55 ^{0}C. O-Na-KMTs X-Uniflock, O-Na-KMTs -2% methyl acrylate.

IV. DISCUSSION

In earlier conducted researches [10] the possibility of increase in wear resistance of stamps of cold deformation from steel У8, due to conducted double tempering with intermediate issue is set. At the same time the first tempering spent from the increased temperatures about 1000-1200 ^{0}C for the maximum saturation by defects of a crystal grid, then conducted issue at 450 ^{0}C. After that conducted the second tempering on usually accepted mode (820 ^{0}C) with the issue at 200 ^{0}C on hardness of 58-60 HRC. At the specified mode of heat treatment high resistance to shift (due to growth of defect density of a crystal grid) and to fragile destruction is reached (due to crushing of grain sizes of austenite at recrystallization). The structure of steel after double tempering with intermediate issue represents small needle martensite. Repeatedly similar results are received for steel У10A.

In relation to heat treatment tool steel questions about efficiency of TCP are studied a little. Positive results at implementation of schemes of medium temperature TCP for the spheroidizing annealing are known. However, in the known works practically did not study influence of replacement of normal annealing with thermal cyclic processing on the subsequent structural phase changes and final properties. It is also necessary to emphasize the efficiency of TCP with increase in a alloying of steel falls (from technological effectiveness positions) as more alloy steels for achievement of noticeable positive result demand conducted bigger number of thermal cycles.

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

For the main operations of heat treatment, tool steel (including final tempering and issue) positive results are received at implementation of some schemes of double heat treatment which can be carried to the combined schemes of TCP.

Options of such processing are implemented for У8А, У10А carbon steels. For the tool materials working in the conditions of considerable loadings (small, average and high-alloy high carbon steels) of the scheme of multiple tempering and the more TCP and its "classical" interpretation (as many cyclic processing), are practically not approved. It is connected, according to us, with two basic reasons. First, with really existing difficulties of multiple application and, especially, cyclic processing for tool steel, the classes stated above (it is, once again we will repeat, about tempering operations). This is due to the need to apply high heating temperatures for quenching by the inevitable formation of a defective surface layer during TTZ with the possible subsequent occurrence of cracks within this zone, as well as with the tendency of many of these steels and naphthalene to a fracture.

Respectively, questions of expediency and the possible field of effective application of multiple heat treatment for high-carbonaceous small, average and high-alloy steels instrumental assignment remain opened so far. In the stated work these questions are systematically studied in relation to high-carbonaceous low-alloy steel 9XC in comparative aspect – for some other tool steel brands У10, У12.

As for cooling liquids, it is necessary to cancel that water and oil are widely applied in industry, however they possess a number of shortcomings and cannot meet the needs of modern production. Water is the cheapest and available hardening environment and provides high physical and mechanical properties of metal. At the same time defects of details are generally observed after tempering in water as at the same time cracks are formed and there is a buckling. Oil, unlike water, has lower refrigerating capolyacrylamideity in the range of martensitic transformation that provides sharp decrease in defects on hardening defects. However, cooling speed in many cases is not enough for obtaining required physical and mechanical properties in the perlite interval. Considering all this the class of water-soluble polymers is of great interest as it is possible to receive the hardening environment combining attractions of oil and water. Results of a research of influence the maintenance of polymeric components in hardening liquid in two temperature interval show a possibility of their application as hardening liquid (fig. 6.7).

V. CONCLUSION

1. Application of preliminary high-temperature TCP instead of normal normalization leads to structure formation with a maximum deficiency of the crystal structure. (fig. 1)

2. The optimum temperature interval of the first heating from preliminary TCP makes 1100-1150 ^{0}C.

3. Subsequent final heat treatment including tempering from the standard temperatures and double discrete issue allow saving effect of preliminary high-temperature TCP (fig. 3,4).

4. Using Water-soluble medicine "Uniflock" that manufactured in Uzbekistan as hardening liquid instead of oil is possible.

REFERENCES

1. Fedyukin V.K. Method of thermocyclic processing of metals. – L.: LGU, 1984. - 190 pages.

2. Fedyukin V.K. Thermocyclic processing technology, structure and properties of metal materials. Institute of problems of engineering science of AHCCCO, 1991. – 309 pages.
3. Fedyukin V.K. Thermocyclic processing of metals and details of machines. Leningrad: Mechanical engineering of 1989. - 255 pages.
4. Vorobyova G. D, Skladkova E.E., etc. Structural steels and alloys Polytechnical publishing house, St. Petersburg 2013. – 440 pages.
5. Norkudjayev F.R., Mukhamedov A.A., Khudayberdiev O.R., Norkhudjayeva R.F. “Development of Machine-Building Materials and Details of Machines from the Powders received from Waste of Raw Materials in the Industry of Uzbekistan”. Test Engineering and Management. ISSN: 0193-4120, Volume-83, Issue Mart/April 2020, March 2020. P639-646
6. Berdiyev D.M., Umarova M.A. Ensuring operability of details of agricultural mechanical engineering with method of thermocyclic processing. "Equipment and technology of mechanical engineering" 7th international scientific and practical conference. Collection of scientific works. – OMSK, 2018 of Page 7-12
7. Svyatkin A.V. Implementation of polymeric liquids in practice of modern heat treatment of forgings. "Forge- forming production. Processing of metal pressure". – 2011. No. 8 of Page 32-38.
8. Shakirov Sh.M., Bektemirov B.Sh., Alimbabeva Z.L., Abdurakhmonov Kh.Z., Tursunov T.Kh. “Formation of Structure at Thermodiffusion Chroming of Porous Permeable Materials Based on Iron Powder”. Test Engineering and Management. ISSN: 0193-4120, Volume-83, Issue Mart/April 2020, March 2020. P635-638
9. Lyuta V. Hardening environments. Reference book. Chelyabinsk. Metallurgy, 1990. – 190 pages.
10. Mukhamedov A.A., Berdiyev D.M. Increase in an abrasive wear properties of steel heat treatment with preliminary preparation of structure. The messenger of mechanical engineering, - Moscow, 2018 - No. 9 from 57-59.
11. Joldoshev V.M., Muratova V.S., Morozov E.A. Working off of the modes of thermocyclic processing of steel of P18. International log of experimental education. – 2010 No. 7 of Page 118-118.
12. Oskolkova T. N., Shorokhova O.V. Use of water polymeric cooling medium when tempering alloy steels and modern high technologies. – 2010. No. 9. – Page 178-179.

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020